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Joint Service Aircrew Mask (JSAM) – Joint Strike Fighter (JSF): Speech Intelligibility Performance

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Interim Report

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14. ABSTRACT
Speech intelligibility (SI) measurements were conducted in accordance with American National Standards Institute (ANSI) S3.2 Method for Measuring the Intelligibility of Speech over Communication Systems on the Joint Service Aircrew Mask (JSAM) – Joint Strike Fighter (JSF) with the F-35 Lightning II Generation II (Gen II) Helmet Mounted Display (HMD) flight helmet. SI performance measurements were also collected with EAR Classic foam earplugs and CEP earplugs worn in combination with the helmet and hood. The objective of these measurements was to determine if the JSAM-JSF performance specification requirements were being met: ≥ 75%. The SI scores for all configurations that included an EAR Classic foam earplug in the system (helmet alone or helmet with hood) fell far below the acceptable requirement with scores ranging from 4% to 16%. However, configurations that included communication earplugs in the system far surpassed the SI requirement with an acceptable performance of 88%.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The noise environment in the cockpit of military fighter aircraft can be exceptionally loud at times. Flight helmets are required not only to protect the pilot from noise exposure, but also to provide communication capabilities. Chemical/biological (CB) protection is also required for aircrew in an actual or perceived CB warfare environment. Donning CB protection under a flight helmet can potentially degrade the noise attenuation performance of the helmet and therefore degrade speech intelligibility performance. Speech intelligibility measurements were collected in accordance with American National Standards Institute (ANSI) S3.2 Method for Measuring the Intelligibility of Speech over Communication Systems[1] on the Joint Service Aircrew Mask (JSAM)-Joint Strike Fighter (JSF) and the F-35 Lightning II Generation II (Gen II) Helmet Mounted Display (HMD). Measurements were conducted at the Air Force Research Laboratory (AFRL) acoustic facility at Wright-Patterson Air Force Base (WPAFB) in April 2015. Additionally, measurements were conducted with EAR Classic foam earplugs and Communication Earplugs (CEP) worn in combination with the hood and helmet. The results were compared to the JSAM-JSF Performance Specification[2] requirements for ground and in-flight operations. The speech intelligibility (SI) scores for all configurations that included an EAR Classic foam earplug in the system (helmet alone or helmet with hood) fell far below the acceptable requirement with scores ranging from 4% to 16%. However, configurations that included communication earplugs in the system far surpassed the SI requirement with an acceptable performance of 88%.

1.0 INTRODUCTION

F-35 pilots don the Lightning II Gen II HMD to combat noise in the cockpit and to provide satisfactory voice communications. The helmet system included a Helmet Assembly Unit, fit adjustment and retention system, bi-ocular display unit (including a display and external tinted visors in a down position) mounted to the helmet, generic liner pads, Helmet Integrated System Ltd (HISL) Active Noise Reduction (ANR) earcups (part number JSO2627) and an oxygen mask with customized bayonets (Figure 1).

Figure 1. F-35 Gen II HMD with JSF O_2 Mask (above) and without JSF O_2 Mask (below)

The JSAM-JSF will be worn in combination with the Gen II HMD to provide CB protection to the respiratory system in an actual or perceived CB warfare environment. The JSAM-JSF was designed for individual pilot head/eye, respiratory and percutaneous protection against chemical and biological (CB) warfare agents, and protection against CB agent permeation. When integrated with aircraft-mounted and pilot-mounted equipment, the system will provide combined (simultaneous as required) hypoxia, CB, and anti-G protection. JSAM-JSF included the hood assembly with integrated oxygen mask, torso kit with JSF jacket mounted H-Manifold assembly and JSAM Aircrew Filter Pack (JAFP), ground kit with man-carried Conversational Communications Unit (CCU), and blower with battery and C2A1 filter. Additionally, the JSAM-JSF directly integrated with JSF equipment including a Ground Adapter (GA), CB Pilot Interface Connector (CB PIC), Cartridge-Activated Cutter (CAC), and several communications cords (Figure 2).

Figure 2. JSAM-JSF (left) & JSAM-JSF with Gen II HMD (right)

Noise attenuation measurements were conducted at AFRL in October 2012 to determine if the JSAM-JSF performance specification requirement was met.[3] CEP were included in the helmet/hood configuration in order to improve the noise attenuation performance of the system. CEP earplugs, Figure 3, are passive hearing protection devices with non-custom foam eartips that provided communication capabilities and were vented for use in a high performance military jet aircraft. EAR Classic foam earplugs, Figure 3, have been approved for use in most legacy aircraft to improve noise attenuation. Speech intelligibility measurements of the hood and helmet with both the CEP and EAR Classic foam earplugs were conducted to determine if JSAM-JSF Performance Specification requirements were met.

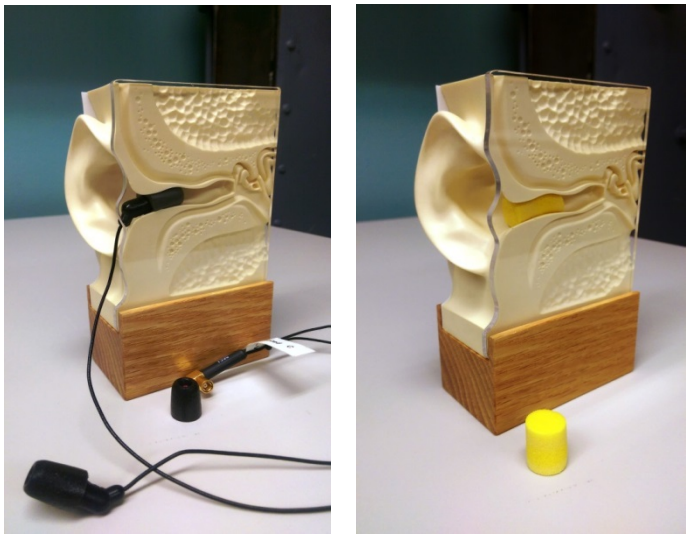

Figure 3. CEPs with Comply™ Canal Tips (left) & EAR Classic Foam Earplug (right)

The objective of this study was to measure the speech intelligibility performance of the JSAM-JSF worn in combination with the Gen II HMD with and without earplugs to determine if the JSAM-JSF met the performance specification requirement as shown below.

JSAM Performance Specification[2], dated 19 August 2013, Requirements 27 a,b:

a. *The system shall provide for intelligible voice communication when aided by a communication amplification device between CB protected pilots and CB protected ground personnel outside of the aircraft in the presence of 71-115 dB background pink noise without loss of CB protection.*

b. *The system shall provide for intelligible voice communication when aided by a communication amplification device between CB protected pilots on the aircraft with flight radio communications system in the presence of 71-115 dB background pink noise without loss of CB protection.*

2.0 METHODS

2.1 Subjects

Ten paid volunteer subjects (5 male, 5 female) participated in the speech intelligibility performance measurements. All subjects had hearing threshold levels less than or equal to 15 dB hearing level (HL) from 125 to 8000 Hz. The subjects ranged in age from 19 to 33 with a mean age of 23 years. The subjects had English as their native language and were trained to contribute as both a talker and a listener. Anthropometric head measurements for each subject were recorded in Table 1.

Table 1. Subjects' anthropometric head measurements

Subject ID	Head Circumference (mm)	Width (mm)	Length (mm)	SNR (mm)	Neck Circumference (mm)
1550	560	140	195	87	360
1564	540	125	180	95	305
1584	570	140	190	81	390
1602	525	125	170	86	305
1616	510	125	175	81	275
1622	525	120	180	70	290
1625	565	123	185	89	350
1629	565	145	190	89	380
1630	510	125	170	87	280
1631	560	140	190	92	365

2.2 Speech Intelligibility

The AFRL VOice Communication Research and Evaluation System (VOCRES) facility was used to measure the speech intelligibility performance of the JSAM-JSF worn in combination with the Gen II HMD with and without earplugs: EAR Classic foam

earplugs and CEP communication earplugs. VOCRES was designed to evaluate voice communication effectiveness in operationally-realistic acoustic environments. The facility consisted of a programmable, high-power sound system housed in a large reverberant chamber, capable of generating high-level (130 dB sound pressure level) pink noise. Ten operator workstations were positioned in the facility (Figure 4), each equipped with a touch-screen display and communication system capable of replicating end-to-end military communication chains (i.e., intercoms, oxygen systems, headsets, microphones, and helmets). In this way, full communication systems, as well as individual system components, may be evaluated under operational conditions to determine the impact these systems might have on speech intelligibility performance.

Figure 4. AFRL's VOCRES facility used to measure speech intelligibility performance

Measurements were conducted in accordance with ANSI S3.2. A limited number of assets reduced the number of listeners per talker to one. Subjects were divided into pairs (1 talker, 1 listener) and subjects would reverse roles during the measurements for a total of 10 talkers/listeners. The Modified Rhyme Test (MRT) was selected for the test material. The MRT consisted of 50 six-word lists of monosyllabic English words. The talker read the phrase "You will mark fill please". The listener then selected a word from a list of six words: fill, kill, bill, will, hill, and till. Each talker completed 3 lists per configuration (Table 2). Measurements were collected in a 115 dB overall sound pressure level (OASPL) noise environment. The talker and listener were in the same noise environment for all configurations.

Table 2. Measurement configuration matrix

Test Number	Configuration	Communication System
0	Gen II HMD	AIC-25
1	Gen II HMD, EAR Classic foam earplugs	AIC-25
2	Gen II HMD, JSAM-JSF, EAR Classic foam earplugs	AIC-25
3	Gen II HMD, CEP	AIC-25
4	Gen II HMD, JSAM-JSF, CEP	AIC-25
5	Gen II HMD, JSAM-JSF, CEP	CCU
6	Gen II HMD, JSAM-JSF, EAR Classic foam earplugs	CCU

For requirement 27a, the JSAM-JSF was worn in the ground configuration mode, with walk out kit and CCU (Figure 5). For requirement 27b, the JSAM-JSF was worn in the flight configuration mode, with torso kit and CB PIC, connected to the supplied air system in AFRL's facility.

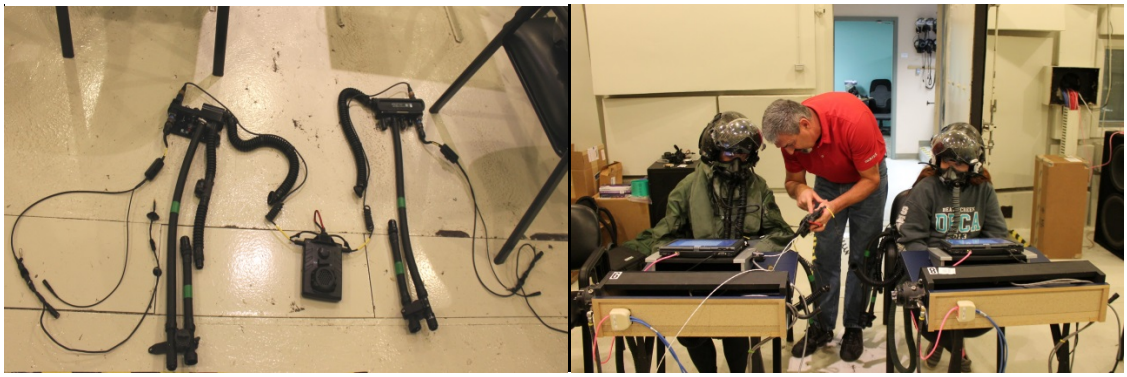

Figure 5. CCU cabling configuration (left) & Subjects connected via CCU (right)

Results were combined for all subjects per configuration. The subjects' scores were adjusted for guessing as described in ANSI S3.2. An overall average was then calculated for all subjects.

$$Score = 2(R - \frac{W}{n-1})$$

Where:

$Score$ = Percent Correct (Adjusted For Guessing)
R = Number Correct
W = Number Incorrect
n = 6 (number of choices available to listener)

In order to meet the requirement, the speech intelligibility score would be ≥75%. However, if the baseline (helmet alone) performance data was already <75% then the performance of the hood and helmet with or without earplugs would be considered acceptable if the score was no worse than 3% lower in comparison to the helmet alone.

3.0 RESULTS

Speech intelligibility data was collected on the Gen II HMD (ANR powered on and off) with JSF oxygen mask, the Gen II HMD and JSF oxygen mask with EAR Classic foam and CEP earplugs, and the Gen II HMD and JSAM-JSF with EAR Classic foam and CEP earplugs using the VOCRES communication system. Speech intelligibility data was also collected on the Gen II HMD and JSAM-JSF with EAR Classic foam and CEP earplugs using the CCU.

Data was collected with ANR powered off for all configurations due to limited ANR functionality (audio in left ear only) from the two original sets of earcups. A third, fully functional set of earcups was secured mid-test and data was collected with ANR powered on, for the listener, during the Gen II HMD and JSF oxygen mask only configuration. ANR provides greater attenuation in the low frequencies and therefore potentially increases the signal to noise ratio. However, the communications delivered by the earcups were bypassed for all configurations involving the CEP. In addition, the benefit of ANR would be minimal, or none at all, for configurations involving the JSAM-JSF and the Gen II HMD caused by the inability to achieve a proper seal around the ears.[2]

3.1 Subjects

Subjects were sized for the JSAM-JSF and Gen II HMD according to his/ her anthropometric head measurements. Subjects' assigned sizes are listed in Table 3. Several subjects were assigned larger sizes for increased comfort (new sizes noted in parentheses in Table 3).

Subjects were scheduled in pairs. Due to limited Gen II HMD sizes (one medium and one large), if both subjects were sized the same, the large helmet was provided to the individual wearing the JSAM-JSF, to increase comfort. For non-JSAM measurements, the large was provided to the subject with the largest head measurements. For all configurations, the talker wore the Gen II HMD with JSF O_2 mask and the earplug for that configuration. The listener wore all the equipment specific to that configuration (Table 4). The Gentex P/N: G018-0555 microphone was embedded in both the JSF O_2 mask and JSAM-JSF. The hoses and breathing apparatus was also the same for both masks. For this reason, in addition to subject comfort, only the listener was placed in the JSAM-JSF for relevant conditions.

Table 3. Subject Sizing Matrix

Subject ID	Hood size	Mask size	Neckdam size	Hood TICN assigned	Hood Serial Number	HMD Size
1550	Medium	MN	3.25	233-06	18801416000007	Large
1564	Small	MN	2.75	143-01	18801408000001	Medium
1584	Medium	SN (MW)	3.25	213-04 (233-08)	18801412000003 (18801416000004)	Large
1602	Small	SN	2.75	122-01	18801403000001	Medium
1616	Small	XSN (S/SN)	2.75	112-04 (122-01)	18801401000001 (18801403000001)	Medium
1622	Small	XSN (S/SN)	2.75	112-02 (122-01)	18801401000004 (18801403000001)	Medium

1625	Small	MN	2.75	143-01	18801408000001	Medium
1629	Medium	MW	3.25	233-07	18801416000009	Large
1630	Medium	MN	3.25	233-08	18801416000004	Medium
1631	Medium	MW	3.25	233-09	18801416000008	Large

3.2 Speech Intelligibility

Speech intelligibility measurements were conducted in AFRL's VOCRES facility using the MRT method described in ANSI S3.2. Measurements were collected with 5 pairs of volunteer subjects wearing the JSAM-JSF and the Gen II HMD with and without earplugs. The average scores for all subjects were calculated (adjusted for guessing) per configuration, Table 4.

Table 4. Speech intelligibility scores

Test Number	Talker Configuration	Listener Configuration	Communication System	Average Score (%)
0	Gen II HMD (ANR off)	Gen II HMD (ANR off)	AIC-25	78.6
1	Gen II HMD, EAR Classic foam earplugs	Gen II HMD, EAR Classic foam earplugs	AIC-25	16.2
2	Gen II HMD, EAR Classic foam earplugs	Gen II HMD, JSAM-JSF, EAR Classic foam earplugs	AIC-25	8.2
3	Gen II HMD, CEP	Gen II HMD, CEP	AIC-25	89.2
4	Gen II HMD, CEP	Gen II HMD, JSAM-JSF, CEP	AIC-25	88.6
5	Gen II HMD, CEP	Gen II HMD, JSAM-JSF, CEP	CCU	89.3
6	Gen II HMD, EAR Classic foam earplugs	Gen II HMD, JSAM-JSF, EAR Classic foam earplugs	CCU	4.5
7	Gen II HMD (ANR off)	Gen II HMD (ANR on)	AIC-25	82.3

The Gen II HMD speech intelligibility performance without ANR powered on scored an average of 78.6% and increased to an average of 82.3% with ANR powered on. The objective of these measurements was to determine if the JSAM-JSF performance specification requirements were being met: $\geq$ 75%. The SI scores for all JSAM-JSF configurations that included an EAR Classic foam earplug in the system (helmet alone or helmet with hood) fell far below the acceptable requirement with scores ranging from 4% to 16%. However, JSAM-JSF configurations that included CEPs in the system far surpassed the SI requirement with an acceptable performance of 88%.

4.0 DISCUSSION

Flight helmets are required in military aircraft for multiple reasons: ballistic/impact protection, reduce noise exposure, and provide communication capabilities. In legacy systems, passive earplugs (foam) were added to the helmet configuration to reduce the level of noise at the ear; unfortunately the added attenuation made it difficult to understand speech. Communication earplugs were then developed to improve both speech intelligibility and noise attenuation. These devices ranged from custom and

generic fit eartips, vented and non-vented systems, with varying shapes and materials. Currently, the F-35 program does not require the pilot to wear any earplug in combination with the Gen II HMD. However, when the JSAM-JSF is required in flight, the noise attenuation of the helmet is degraded. Therefore, earplugs are required to reduce the level of noise exposure.[2]
The results from the speech intelligibility measurements revealed that the EAR Classic foam earplugs are not a viable option to provide acceptable communication capabilities. However, a communication earplug, like CEP, will improve noise attenuation of the helmet and hood and improve the speech intelligibility performance.

It should be noted that the communication system in AFRL's VOCRES facility was not representative of F-35 communication system. In order to simulate the volume control the pilots have in the F-35 communication system, the VOCRES facility limited the amount of gain in their system to 102 dB at 1000Hz (as provided by Lockheed Martin). In-flight and ground speech intelligibility measurements should be conducted with the F-35 communication system to confirm operationally relevant performance.

5.0 CONCLUSIONS

Speech intelligibility data was conducted at AFRL in accordance with ANSI S3.2 in April 2015. Measurements were collected on the JSAM-JSF and the Gen II HMD with and without EAR Classic foam and CEP earplugs to determine if JSAM-JSF Performance Specification[3] requirements were met. The requirement of $\geq 75\%$ was met when the JSAM-JSF and the Gen II HMD was worn with CEP communication earplugs for both in-flight and ground operations. However, when EAR Classic foam earplugs were worn, the speech intelligibility performance data was scored $\leq 16\%$ for all configurations.

To ensure adequate noise attenuation and acceptable speech intelligibility performance, the JSAM-JSF, when worn under the Gen II HMD, should be donned with a communication earplug.

6.0 REFERENCES

1. ANSI S3.2-2009 American National Standard Method for Measuring the Intelligibility of Speech over Communication Systems
2. Performance Specification for Joint Service Aircrew Mask-Joint Strike Fighter System, 19 August 2013.
3. Gallagher, H.L. (2013) Noise Attenuation Performance of the Lightning II Generation II Helmet when worn in combination with the Joint Service Aircrew Mask (JSAM) – Joint Strike Fighter (JSF). AFRL-RH-WP-TR-2013-0021.